Aquatic Loadings from Wind Scavenged Tailings Particulates Near Flin Flon

October - November, 1984

Water Standards and Studies Report #85-4

Manitoba
Environment and
Workplace Safety
and Health

AQUATIC LOADINGS FROM WIND SCAVENGED TAILINGS PARTICULATES NEAR FLIN FLON,

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SUMMARY

Strong winds during late October and early November, 1984 scavenged particulates from the Hudson Bay Mining and Smelting Company tailings disposal area at Flin Flon, Manitoba. The events aroused local concerns about several issues including the nature of the dispersed particulates and possible impacts upon local lakes and aquatic organisms.

Site inspection and sampling were conducted January 8-10, 1985. Single 10 cm x 10 cm columns of snow and ice were collected from twenty-six sites located on lakes within ten kilometres of the smelter stack. These were analyzed for metal and sulphate content. Water samples were also collected from each site and analyzed for general physicochemical parameters.

Total depositions of sulphate and metals were calculated for each site and regressions of depositions over distance were developed. Regression derived concentrations were compared to historical maxima and minima in order to estimate depositions attributable to windborne tailings particulates. Potential impacts upon local lakes and aquatic fauna were then assessed on the basis of dilution by the surface one metre layer on each lake and comparison to current water quality and surface water quality objectives.

The data indicated that windborne tailings particulates did not raise the rates of cadmium, copper, lead and zinc depositions detectably above local background. However, the windborne tailings particulates did increase the rates of iron and sulphate depositions above local background. Iron depositions greater than local background were detected within a two kilometre radius of the smelter stack. However, these depositions had no impact upon local aquatic organisms and no statistically significant impact upon the water physicochemistry of local lakes. Sulphate depositions greater than local background were detected within a four to six kilometre radius of the smelter stack, but could not be quantified with certainty. Thus, although total sulphate depositions had the potential to impact negatively upon local lakes and aquatic fauna, impacts attributable solely to sulphates from windborne tailings particulates could neither be demonstrated nor disproven.

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1. (a) Letter, Leefe to Brown, November 27, 1984.

(b) Letter, Brown to Leefe, December 11, 1984.

(c) Memorandum, Brown to Warner, April 1, 1985.

(d) Memorandum, Brown to Wotton, April 1, 1985.

(e) Letter, Brown to Leefe, April 1, 1985.

2. (a) Sampling site and sample characteristics.

(b) Metal and sulphate concentrations in thawed snow-ice samples.

(c) Metal and sulphate total calculated depositions.

(d) Water chemistry results.

1.0 INTRODUCTION

Water Standards and Studies Section received a letter from Mr. Bill Leefe, Smelter Safety Committee Co-Chairperson, United Steelworkers of America Local 7106, Flin Flon (Appendix (a)). The letter, dated November 27, 1984, expressed concern about air borne particulates originating from the Hudson Bay Mining and Smelting Company tailings pond at Flin Flon. Specific concerns cited included the nature of the particulates, possible impacts upon people, wildlife and lakes, and recommended remedial action. A Water Standards and Studies Section letter dated December 11, 1984, (Appendix 1(b)) acknowledged receipt of Mr. Leefe's letter and confirmed that the concern would be investigated.

Most public inquiries and requests from other government agencies are adequately addressed by conducting a relatively minor amount of research and encapsulating the results in the form of letters or memoranda. However, the scope of Mr. Leefe's concern required a considerable amount of research. The detail of the results, in turn, necessitated the preparation of a detailed response. The present report constitutes a formal record of the investigation of Mr. Leefe's concern.

The scope of Mr. Leefe's concerns included several areas beyond the mandated responsibility of Water Standards and Studies Section. As soon as loading rates could be calculated, concerns regarding possible impacts upon human health and upon wildlife were forwarded to the Environmental Health Services Branch and to the

Terrestrial Standards and Studies Section (respectively) for direct response (Appendicies 1(c) and 1(d), respectively). These actions and an interim progress report were communicated to Mr. Leefe in a letter dated April 1, 1985 (Appendix 1(e)).

The present study sought to address the remainder of Mr. Leefe's concerns. Specific objectives established to achieve this goal included:

a) to determine metal and sulphate airborne tailings particulate loading rates within 10 kilometres of the Flin Flon tailings pond and,

b) to assess the potential impacts of the airborne tailings particulates upon lakes of the area.

2.0 METHODS

The general approach to this issue involved three distinct steps. Firstly, the actual depositions of metals and sulphate were measured. Second, resultant values were compared with historical background in an attempt to delineate the area receiving depositions of airborne tailings materials. Finally, impacts upon lakes were assessed by a comparison of observed deposition rates with present water quality and with water quality objectives.

2.1 RATIONALE

Mr. Leefe's letter (Appendix 1(a)) contained an element of uncertainty regarding the precise date(s) on which the tailings pond surface was scavenged by winds. A review of Flin Flon atmospheric data for the period October 15, 1984 to November 15, 1984 (A. Jackson, pers. comm.) indicated that mean hourly wind speeds exceeded 14 kph on nine days. Wind directions during these events varied from north (e.g. October 15 and 20, 1984) to south (e.g. October 25, 1984) and from south-east (e.g. October 16, 1984) to north-west (e.g. October 27 and 31, November 1, 1984) and north-east (e.g. October 17 and November 14, 1984). This suggested that tailings particulate plumes might be found in all directions from the tailings pond. Accordingly, field sampling was conducted in all directions from the tailings pond within provincial (Manitoba) boundaries.

2.2 FIELD PROCEDURES

The Hudson Bay Mining and Smelting Company stack at Flin Flon was considered "point of origin" for the purposes of the present study. Hence, sample radia and distance to various sampling sites originated at the stack. A total of twenty-six sampling sites were established along six radia (Figure 1). Sampling sites were numbered according to chronological sampling order. Direct distances to each site and direction from the stack were estimated from topographical maps (Appendix 2(a)).

Single snow-ice samples were collected at each site. A column of snow somewhat greater than ten centimetres square was cleared by shoveling. The height of the column was measured to the nearest 0.5 centimetres. A stainless steel knife was then used to carve the column to a 10 cm. x 10 cm. dimension. The entire column was deposited in a labeled 47 cm x 112 cm x 0.08 mm Cilux bag. Surface ice at the base of the column was chiseled to a depth of approximately 2.5 cm. below the slush ice - true ice interface* and added to the sample. This procedure was adopted in order to preclude the exclusion of particulates which may have become embedded in upper ice layers. All samples were maintained in a frozen state until delivery to the W. M. Ward Technical Services Laboratory.

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* The interface between the white colored, opaque slush ice and the bluish, clear, true ice was readily apparent.

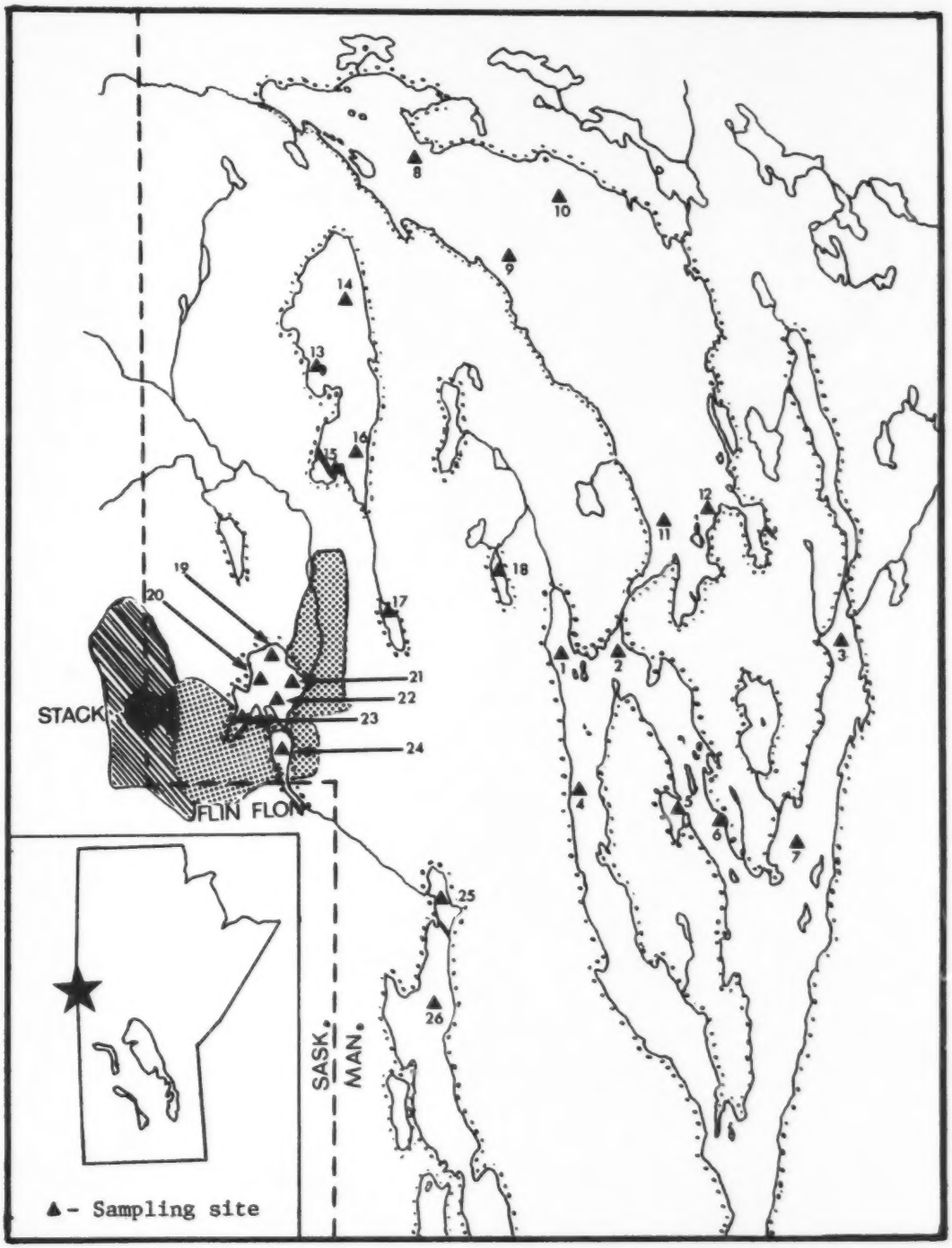

FIGURE 1: SAMPLING SITES ON LAKES NEAR FLIN FLON

Single sets of water samples were also collected at each site. All sample containers were triple rinsed on site prior to filling by immersion. Samples were stored in coolers and shipped at each days end by scheduled bus service to the W. M. Ward Technical Services Laboratory.

Sampling sites 1 to 12 were sampled January 8, 1985, sites 13 to 23 were sampled January 9, 1985, and sites 24 to 26 were sampled on January 10, 1985.

2.3 ANALYTICAL PROCEDURES

Water chemistry analyses were performed by staff of the W. M. Ward Technical services Laboratory according to procedures described by Sorba et al (1980).

Frozen snow-ice samples were individually weighed to the nearest 0.1 grams. The tare weight of the sample bag (76.9 g) was deducted and the resultant weight was converted to liquid column by assuming one gram of sample equivalent to one millilitre of water. Bags and contents were then propped in one litre plastic containers and allowed to thaw. The natural thawing and settling process (on lakes) was simulated by permitting the thawed samples to sit undisturbed for fourteen days without acidification (i.e. preservation). Aliquots were then withdrawn and analyzed by staff of the W. M. Ward Technical Services Laboratory according to procedures described by Sorba et al (1980).

Total depositions were calculated* for sulphate and for the metals at each site. Regressions over distance from the stack were developed for total depositions. Theoretical concentrations at one kilometre intervals were then estimated from the regressions. Historical January maximum (1981) and minimum (1984) depositions attributable to stack emissions were extracted from data published by Phillips et al (1983) and from Phillips (pers. comm.) respectively. Again, regressions were developed** and theoretical concentrations at one kilometre intervals were estimated. Estimated historical maxima and minima were then deducted from the estimated January 1985 total depositions. The resultant differences were considered maximum and minimum depositions attributable to airborne particulates originating from the tailings pond.

The potential to impact upon water chemistry was examined on the basis of dilution by one cubic metre of water. This was viewed as the maximum potential "shock" or "worst case" scenario liable to be experienced by lakes during spring thaw. Diluted concentrations were also compared to current surface water quality and to surface water quality objectives (Williamson, 1983).

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* Calculated with the formula $D = CV/A$
Where D = total deposition in mg/m^2
C = sample concentration in mg/L
V = volume of sample in L
A = area sampled in m^2

** The risk of potential error due to an apparent anomaly in the data of Phillips et al (1983) and of Phillips (pers. comm.) was reduced by using mid-distances and mid-concentrations instead of reported values for (their) stations 1 and 5.

3.0 RESULTS AND DISCUSSION

Metal and sulphate concentrations in thawed snow-ice samples are detailed in Appendix 2(b) and total calculated depositions are presented in Appendix 2(c). Appendix 2(d) lists the water chemistry results.

3.1 METAL AND SULPHATE DEPOSITIONS

Regressions developed from total calculated metal and sulphate depositions (mg/m^2) over distance from the smelter stack (km) are defined in Table 1. Estimated total rates of deposition at one kilometre intervals from the smelter stack are also listed in Table 1. Recent estimated January minima and maxima are presented in Tables 2 and 3, respectively.

The results, indicating an inverse power curvilinear relationship between distance from the smelter stack and depositions of most metals and sulphate, were consistent with the work of previous investigators (Phillips et al, 1983; Hogan and Wotton, 1980; Franzin, 1979). Significant correlations ($t\alpha = 0.05$) supportive of this relationship were observed for zinc, copper, cadmium, iron and sulphate. Unlike the work of Phillips et al (1983) and Franzin (1979), a significant correlation was not observed for the relationship between lead deposition and distance from the smelter stack. Nickel was not detected in samples of the present study and presumably was not a detectable component of smelter stack emissions.

TABLE 1: Regressions and Estimated Rates of Deposition (January 1985)

Where $mg/m^2=a(Km)^b$	Cd	Cu	Pb	Zn	Fe	SO_4 *
a	2.37	106.07	0.02	786.89	161.01	14725.58
b	-1.16	-1.69	0.89	-1.16	-2.97	-2.33
r^2	0.61	0.60	0.06	0.52	0.54	0.64
Ho:β=0 (t_{α}=0.05)	Reject	Reject	Accept	Reject	Reject	Reject
Kilometres	**Estimated Rates of Deposition (mg/m^2)**					
1	2.37	106.07	Nil	786.89	161.01	14725.58
2	1.06	32.82	Nil	352.71	20.58	2938.33
3	0.66	16.52	Nil	220.58	6.18	1144.58
4	0.47	10.15	Nil	158.10	2.63	586.31
5	0.37	6.96	Nil	122.11	1.36	348.97
6	0.30	5.11	Nil	98.87	0.79	228.39
7	0.25	3.94	Nil	82.71	0.50	159.59
8	0.21	3.14	Nil	70.86	0.34	116.99
9	0.19	2.57	Nil	61.83	0.24	88.96
10	0.16	2.15	Nil	54.73	0.17	69.63

* Sulphate data from sampling sites 25 and 26 were excluded from the calculations because it appeared that fly ash from the nearby waste disposal ground had contaminated sulphate residues. However, it should be noted that inclusion of the suspect values also produced an acceptance of the null hypothesis where:

$a = 16875.13$
$b = -2.25$
$R^2 = 0.50$

TABLE 2: Regressions and Minimum Estimated Rates of Deposition * (January 1984)

Where $mg/m^2=a(Km)^b$	Cd	Cu	Pb	Zn	Fe	SO_4
a	4.06	465.10	190.90	2778.87	30.13	194.63
b	-1.37	-2.00	-2.34	-2.13	-0.77	-0.58
r^2	0.81	0.98	0.68	0.98	0.81	0.79
Ho:β=0 ($t\alpha$=0.05)	Reject	Reject	Reject	Reject	Reject	Reject

Kilometres	Estimated Rates of Deposition (mg/m^2)					
1	4.06	465.10	190.90	2778.87	30.13	194.63
2	1.57	116.14	37.62	633.62	17.71	130.04
3	0.90	51.59	14.54	266.84	12.97	102.71
4	0.60	29.00	7.41	144.47	10.41	86.88
5	0.44	18.56	4.39	89.76	8.77	76.30
6	0.35	12.88	2.87	60.84	7.62	68.62
7	0.28	9.46	2.00	43.80	6.77	62.74
8	0.23	7.24	1.46	32.94	6.11	58.05
9	0.20	5.72	1.11	25.62	5.59	54.20
10	0.17	4.63	0.87	20.47	5.15	50.98

* Data from Phillips (pers. comm).

TABLE 3: Regressions and Maximum Estimated Rates of Deposition * (January 1981)

Where $mg/m^2=a(Km)^b$	Cd	Cu	Pb	Zn	Fe	SO_4
a	17.56	228.78	702.2	97741.76	140.20	2769.05
b	-1.11	-1.27	-1.63	-2.10	-1.03	-1.13
r^2	0.78	0.49	0.97	0.97	0.91	0.99
Ho:β=0 ($t\alpha$=0.05)	Reject	Accept	Reject	Reject	Reject	Reject
Kilometres	Estimated Rates of Deposition (mg/m^2)					
1	17.56	-	702.20	97741.76	140.20	2769.05
2	8.11	-	226.62	22871.63	68.85	1267.64
3	5.16	-	116.95	9779.41	45.42	802.60
4	3.74	-	73.14	5351.98	33.81	580.31
5	2.92	-	50.82	3353.11	26.89	451.25
6	2.38	-	37.74	2288.39	22.31	367.42
7	2.01	-	29.35	1656.72	19.04	308.82
8	1.73	-	23.60	1252.37	16.60	265.66
9	1.52	-	19.48	978.47	14.71	232.63
10	1.35	-	16.40	784.63	13.21	206.58

* Data from Phillips et al (1983).

The metals may be ranked in order of decreasing rates of deposition. Based upon estimated depositions at 5 kilometres from the smelter stack, metals from the present study would be ranked in decreasing order as zinc, copper, iron and cadmium (Table 1). Excepting the exclusion of lead, this order was consistent with the work of the previous investigators (ibid, op cit). The significance of this reproducibility is that it supports the validity of using historical data (e.g. Tables 2 and 3) as background to the present study.

3.1.1 DEPOSITIONS ATTRIBUTABLE TO TAILINGS PARTICULATES

The deduction of historical maxima and minima from depositions of the present study were expected to yield an indication of metal and sulphate deposition attributable to sources other than fallout from smelter stack emissions*. These results (Table 4) were considered interpretable as depositions attributable primarily to wind blown tailings particulates.

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*It is recognized that extrapolation of curvilinear relationships beyond actual data origin (i.e. at the 1, 2, 3 and 4 kilometre intervals for Tables 2 and 3) may not be a valid statistical procedure. The present study uses extrapolation only to approximate the area of the dispersion zone in the absence of "hard" background data.

TABLE 4: Estimated Maximum and Minimum Rates* of Metal and Sulphate Deposition (mg/m^2) Attributable to Tailings Particulates

Estimated Maximum ** Rates of Deposition (mg/m^2) Attributable to Tailings Particulates

Kilometres	Cd	Cu	Pb	Zn	Fe	SO_4
1	-	-	-	-	130.87	14530.95
2	-	-	-	-	-	2808.29
3	-	-	-	-	-	1041.87
4	-	-	-	"13.63"	-	499.43
5	-	-	-	"32.35"	-	272.67
6	-	-	-	"38.03"	-	159.77
7	-	-	-	"38.91"	-	96.85
8	-	-	-	"37.92"	-	58.94
9	-	-	-	"36.21"	-	34.76
10	-	-	-	"34.26"	-	18.65

Estimated Minimun *** Rates of Deposition (mg/m^2) Attributable to Tailings Particulates

Kilometres	Cd	Cu	Pb	Zn	Fe	SO_4
1	-	-	-	-	20.81	11956.53
2	-	-	-	-	2.87	1670.69
3	-	-	-	-	-	341.98
4	-	-	-	-	-	6.00
5	-	-	-	-	-	-
6	-	-	-	-	-	-
7	-	-	-	-	-	-
8	-	-	-	-	-	-
9	-	-	-	-	-	-
10	-	-	-	-	-	-

* "-" denotes that Table 1 values were less than the subtractor.

** Calculated on the basis of table 2 values deducted from the respective Table 1 values.

*** Calculated on the basis of Table 3 values deducted from the respective Table 1 values.

Estimated historical maxima and minima for cadmium, copper and lead depositions were greater at all distance intervals than estimated depositions encountered in the present study (Table 4). This indicated that settling of windborne tailings particlates failed to raise the rates of cadmium, copper and lead depositions detectably above background. This was expected since the tailings reportedly contain copper in the range of 0.06% to 0.39% and lead in the range of 0.01% to 1.0% (Hudson Bay Mining and Smelting Co. et al, 1976).

Deduction of estimated zinc depositions encountered during the present study from historical maxima and minima yielded a false "tail" beginning at 3 to 4 kilometres from the smelter stack (Table 4). This "tail" was considered misleading because depositions of zinc near the alleged source (i.e. the tailings pond) were not detectably above background. The "tail" was thus considered an artifact of the regressions and it was concluded that settling of windborne tailings particulates failed to raise the rate of zinc deposition detectably above background. This conclusion was consistent with reported tailings zinc concentration ranging from 0.48% to 1.10% (Ibid).

Deduction of estimated iron depositions encountered during the present study from historical maxima and minima suggested that settling of windborne tailings particulates had indeed raised the rate of iron depositions detectably above background. The zone detectably influenced by loadings of tailings iron appeared confined at minimum to an area within approximately 1 kilometre of the smelter stack and, at maximum, to an area within approximately 2 kilometres of the smelter stack (Figure 2). Loadings of iron had been anticipated since iron content in tailings were reported to range from 21.4% to 24.8% (Ibid).

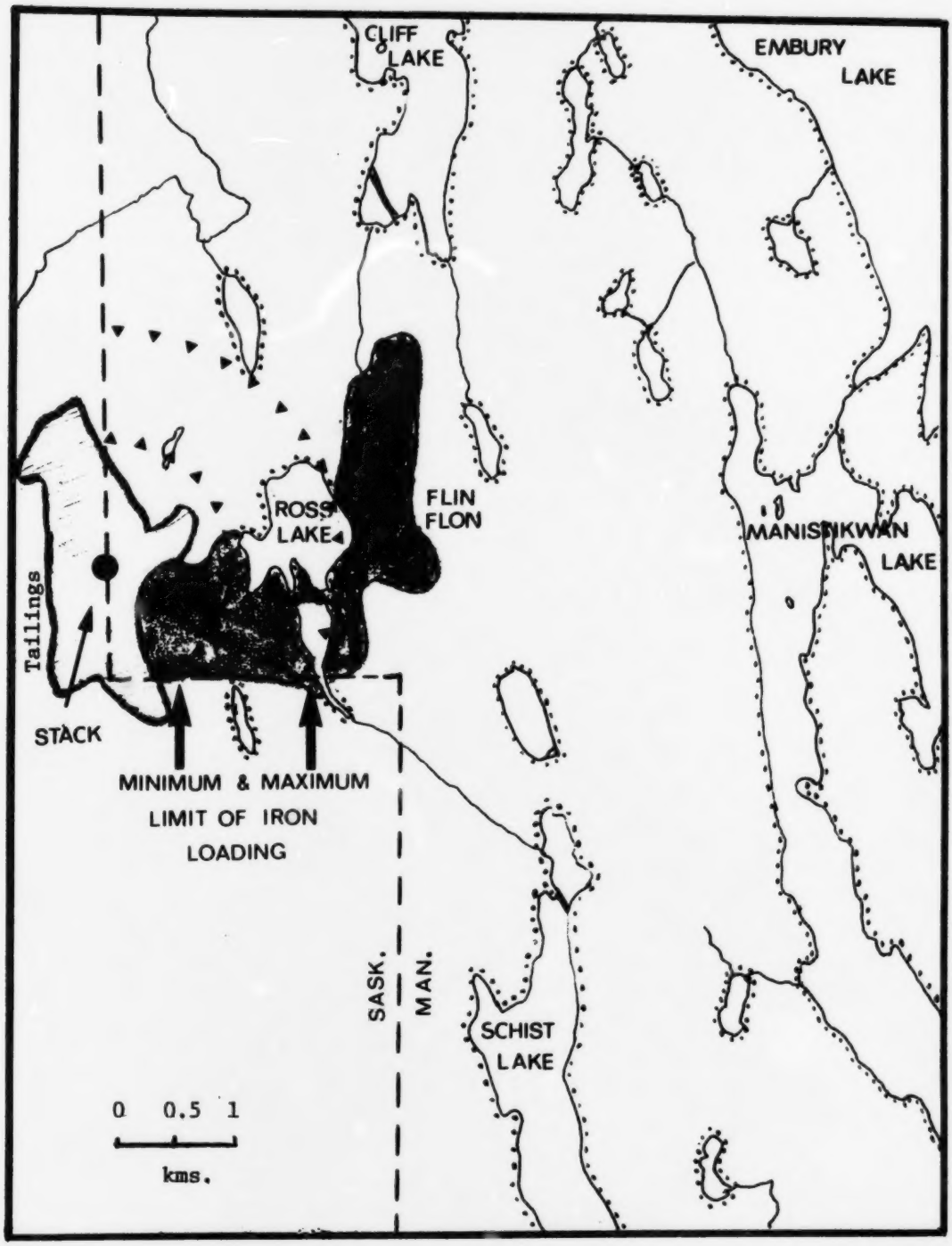

FIGURE 2: AREA RECEIVING DETECTABLE LOADINGS OF IRON FROM TAILINGS PARTICULATES

Sulphate results (Table 4) also showed the influence of detectable loadings attributable to the settling of windborne tailings particulates. The minimum size of the zone detectably influenced by loadings of tailings sulphate appeared confined to within approximately 4 kilometres of the smelter stack (Figure 3). The maximum zone of influence appeared to extend somewhat farther than 10 kilometres (Figure 3). However, the apparent confinement of iron loadings to an area in close proximity with the stack, and the observed total sulphate depositions (Table 5), suggested that tailings particulate sulphate loadings were actually confined to an area within 4 to 6 kilometres from the stack. Loadings of sulphate had been anticipated since the ores processed at Flin Flon are primarily sulphides (Davies et al, 1961) and since the sulphate content in tailings ranged from 5.21 to 116.20 meq/100 gm (op cit).

Since precise quantification of loadings attributable solely to airborne tailings particulates was not possible, approximations were estimated at less than mean observed total depositions for varying distance intervals within the respective impact zones. Mean observed total depositions calculated at distance intervals of 2 kilometres are presented in Table 5.

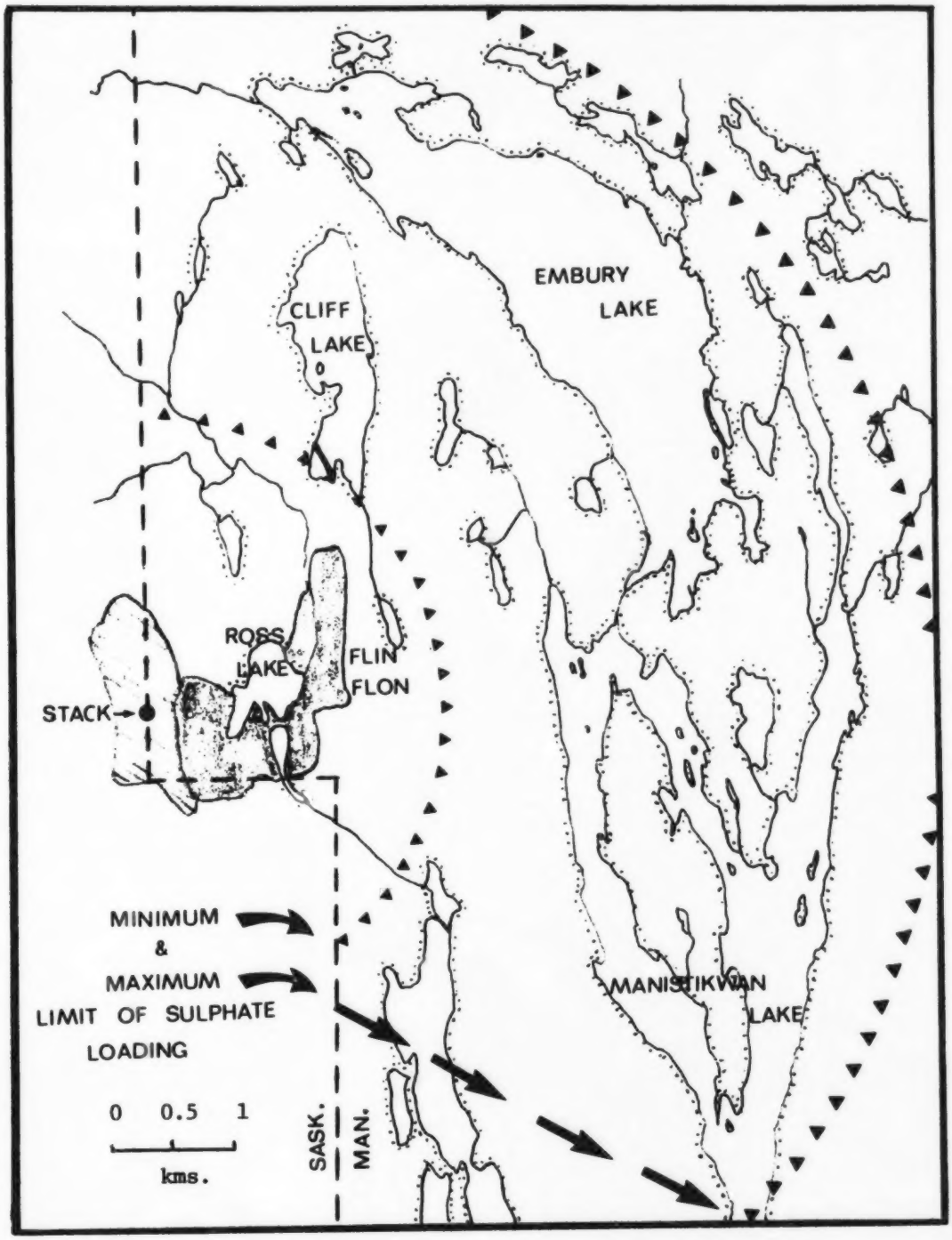

FIGURE 3: AREA RECEIVING DETECTABLE LOADINGS OF SULPHATE FROM TAILINGS PARTICULATES

TABLE 5: Mean Total Iron and Sulphate Depositions Within Estimated Zone of Tailings Particulate Loadings

Distance Interval (km)	Iron (mg/m^2)	Sulphate (mg/m^2)	N
< 2	38.24	12,161.0	6
2-4	-	371.2	2
4-6	-	314.1	5*
6-8	-	258.1	7
>8	-	50.9	3

* Sampling sites 25 and 26 have been excluded from calculations because of suspected sulphate contamination via airborne particulates emanating from the local waste disposal grounds. Contamination was indicated by the presence of ashed paper products dispersed over the snow.

3.2 IMPACTS UPON LAKES

The discussion is limited to iron and sulphate since these were implicated in depositions of tailings particulates.

3.2.1 WATER CHEMISTRY

Water chemistry data are detailed in Appendix 2(d) and are summarized in Table 6.

3.2.1.1 IRON

The extent of iron loadings attributable to tailings particulates was estimated to extend a maximum of approximately two kilometres from the smelter stack. Ross Lake was the only waterbody of appreciable size located within the Manitoba portion of this zone.

The mean rate of iron deposition within two kilometres of the smelter stack was estimated at 38.24 mg/m^2 (Table 5). Assuming even distribution through only the uppermost metre* of lake water during spring breakup, the fraction of water column iron potentially contributable (i.e. the sum of tailings particulate iron and stack fallout iron) was calculated at (38.24 mg/1000 L) 0.03824 mg/L. The mean iron concentration of Ross Lake during the January, 1985 period of study was determined to be 0.08$\pm$ 0.02 mg/L (Table 6). Charging the uppermost metre of Ross Lake* with the calculated maximum of 0.0382 mg/L of additional iron would not raise the mean iron concentration significantly (t_{α} = 0.05) since "t" was calculated at 1.57. Thus it

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* This would constitute a "worst case" scenario

TABLE 6: Mean Surface Water Chemistry Features for Seven Flin Flon Area Lakes, January 1985

Parameter* χ/δ	Embury Lake (N=5)	Cliff Lake (N=4)	Manistikwan Lake (N=7)	Schist Lake (N=2)	Ross Lake (N=6)	Grant Lake (N=1)	Unnamed Lake (N=1)
Conductivity ($\mu S/cm$)	129 /1.6	130 /6.6	167 /17.9	858 /15.6	1682 /69.1	238 -	106 -
pH (Units)	7.51 -	7.58 -	7.60 -	7.33 -	6.72 -	6.80 -	6.65 -
Total Alkalinity ($CaCO_3$ mg/L)	47.0 /1.15	48.0 /1.63	64.5 /7.54	71.0 /1.41	36.0 /3.58	94.0 -	46.0 -
Alkalinity (HCO_3 mg/L)	57.4 /1.44	58.6 /2.00	78.1 /9.78	86.6 /1.70	43.9 /4.36	115 -	56.1 -
Ext. Arsenic (mg/L)	0.001 /0.0009	0.002 /0.0005	0.003 /0.0008	0.003 /0.0007	<0.003 /0.003	0.002 -	0.002 -
Ext. Cadmium (mg/L	0.001 /0	0.001 /0	0.001 /0.0004	<0.001 /0	0.009 /0.002	0.001 -	0.001 -
Ext. Copper (mg/L)	0.01 /0	0.01 /0	0.01 /0	<0.01 /0	0.03 /0	0.01 -	0.03 -
Ext. Lead (mg/L)	<0.005 /0	<0.005 /0	<0.005 /0	<0.005 /0	<0.005 /0	<0.005 -	<0.005 -
Ext. Nickel (mg/L)	0.006 /0.002	<0.005 /0.0005	<0.005 /0	<0.008 /0.004	<0.007 /0.003	<0.005 -	<0.005 -
Ext. Zinc (mg/L)	0.29 /0.03	0.28 /0.05	0.40 /0.08	0.39 /0.03	2.14 /0.22	0.39 -	0.79 -
Ext. Calcium (mg/L)	19.0 /0.44	19.0 /0.76	24.8 /2.83	134.5 /6.36	257 /9.2	38.0 -	17.5 -
Ext. Magnesium (mg/L)	5.23 /0.13	5.29 /0.21	7.33 /1.02	12.90 /0.14	15.23 /0.36	8.10 -	4.08 -
Hardness ($CaCO_3$,g/L)	68.8 /1.43	69.1 /2.74	92.0 /11.17	390 /17.0	706 /22.8	128 -	60.8 -
Ext. Iron (mg/L)	<0.02 /0.004	<0.02 /0	<0.02 /0	<0.02 /0	0.08 /0.02	0.22 -	0.42 -

* χ = mean δ = standard deviation.

was concluded that deposition of tailings particulates scavenged by winds during late fall, 1984 did not result in a statistically significant elevation of iron concentrations in local lakes.

3.2.1.2 SULPHATES

The extent of sulphate loadings attributable to tailings particulates was estimated to extend a minimum of four kilometres and a maximum of slightly more then ten kilometres from the smelter stack. The extent of iron loadings suggested that the lesser figure (i.e. 4-6 km) was the more realistic for sulphates.

The dissociation of various sulphate compounds is of concern rather than the presence of the sulphate anion itself. Sulphate compounds passing through water or other matrices have a tendency to dissociate and, by base exchange, lose cations for the free H^+ radical (Hutchinson, 1957). The resultant sulphuric acid reduces the pH of water and renders it less hospitable for aquatic organisms. Sulphuric acid formation is contingent upon rates of dissociation and upon the presence of buffering agents such as calcium and magnesium which neutralize acids. Since the various species of sulphates dispersed by winds could not be investigated, dissociation rates could not be determined. Hence theoretical maximum pH values* rather than accurate estimates were calculated.

---

* Calculated by: $-\log \frac{2A}{B} C$

where A = Atomic weight of H^+
B = Atomic weight of SO_4 =
C = Concentration of sulphate within the dispersion zone

The most intensive deposition of sulphates occurred within two kilometres of the smelter stack (Table 5). The mean total rate of deposition within this zone, 12,161 mg/m^2 (Table 5), had a calculated theoretical maximum ability to reduce a cubic meter of neutral water to a pH of 3.57 units. The zone located within two to four kilometres of the stack had a mean total rate of sulphate deposition of 371.2 mg/m^2 (Table 5). This had the calculated theoretical maximum ability to reduce a cubic meter of neutral water to a pH of 5.11 units. The zone located within four to six kilometres of the stack had a mean total rate of sulphate deposition of 314.1 mg/m^2 (Table 5) and a calculated theoretical maximum ability to reduce a cubic meter of neutral water to a pH of 5.27 units.

However, the calculated theoretical maximum pH values represented a "worst case" scenario and assumed the improbable events of complete dissociation and an absence of buffering potential. Additionally, the values were calculated on the basis of total deposition (i.e. the sum of tailings particulates, smelter stack fallout and other sources) and the fraction attributable to tailings particulates could not be accurately established. Thus it was neither demonstrated nor disproven that sulphate deposition originating with wind scavenged tailings particulates caused a depression of pH values in surface waters of lakes located within four to six kilometres of the smelter.

3.2.2 AQUATIC ORGANISMS

The protection of both cool and cold water aquatic organisms requires that iron concentrations not exceed 1.0 mg/L (Williamson, 1983). Ross Lake, the only appreciably sized waterbody which received tailings particulate iron, had a calculated maximum mean iron concentration of (0.0382 mg/L + 0.08 mg/L) = 0.1182 mg/L. Thus it was concluded that iron loadings from the deposition of tailings particulates scavenged by winds during the late fall, 1984 had no impact upon local aquatic organisms.

A similar conclusive statement could not be made for sulphate depositions which originated in the same manner. The protection of both cool and cold water aquatic organisms requires that pH levels be maintained in the 6.5 t0 9.0 range. Theoretical calculations indicated a potential for surface waters of lakes located within four to six kilometres of the smelter stack to suffer a depressed pH level. However, it was neither demonstrated nor disproven that a surface water pH depression occurred. Thus, impacts upon aquatic organisms could neither be demonstrated nor disproven.

4.0 CONCLUSIONS

It was concluded that with respect to late fall, 1984 wind scavenged tailings particulates:

1. The deposition of windborne tailings particulates failed to raise the rates of cadmium, copper, lead and zinc depositions detectably above local background.
2. The deposition of windborne tailings particulates detectably raised the rate of iron deposition above local background within a two kilometre radius of the smelter stack.
3. The deposition of windborne tailings particulates detectably raised the rate of sulphate deposition above local background to the area within a four to six kilometre radius of the smelter stack.
4. Iron depositions due to windborne tailings particulates had no detected impact upon local aquatic organisms and no statistically significant impact upon the water physicochemistry of local lakes.
5. Although total sulphate depositions had the potential to impact negatively upon local lakes and aquatic fauna, impacts attributable solely to sulphates from windborne tailings particulates could neither be demonstrated nor disproven.

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6.0 ACKNOWLEDGEMENTS

The suggestions, advice and data provided by Floyd Phillips, Dale Jones and Dale McEachern of the Terrestrial Standards and Studies Section are gratefully acknowledged. The extra efforts taken by Paulette Douville and Al Jakilazek and staff of the W. M. Ward Technical Services Laboratory was greatly appreciated. Atmospheric data provided by the Air Pollution Section was also appreciated.

APPENDICES

UNITED STEELWORKERS OF AMERICA
DISTRICT 3 LOCAL 7106
68 CHURCH STREET, FLIN FLON, MANITOBA R8A 1K7
H. LEN STEVENS, DIRECTOR PHONE 204 /687-4448

November 27,1984

Mr. Dennis Brown,
Section Head - Water Standards and Studies,
Environmental Services Branch,
Box 7, Building 2,
1391 Tuxedo Avenue,
Winnipeg, Manitoba
R3N OH6

Dear Mr. Brown,

During the latter part of October or the early part of November, there was a severe wind storm in the Flin Flon area. It caused materials from the Hudson Bay Mining and Smelting Company tailings pond to become air borne.

I am very concerned about the levels of zinc and whatever else that might have become blown onto the ice forming on Ross Lake, and onto the surrounding dwellings.

Could you investigate this matter and let me know what the levels and kinds of contaminents we were exposed to in this area?

If the levels are high and are dangerous to us as people, the wild life in the area, and the lakes themselves, what are our alternatives ? What can we do to try and correct this pollution problem ?

Your help in this matter is greatly appreciated.

Yours truly,

Bill Leefe
Smelter Safety Committee Co-Chairperson.

NOV 30 1984

COPY

December 11, 1984

Mr. Bill Leefe,
Smelter Safety Committee Co-Chairperson,
United Steelworkers of America,
District 3, Local 7106,
68 Church Street,
FLIN FLON, Manitoba
R8A 1K7

Dear Mr. Leefe:

I have received your letter dated November 27, 1984 stating your concerns with respect to wind borne tailings being deposited on lake ice in the vicinity of Flin Flon. Staff of Water Standards and Studies Section will investigate the concern during the week of January 7 - 11, 1985. Arrangements have been made for chemical analyses. You will be informed of the results prior to spring thaw.

If I can be of further help in his matter, please call me at 1-945-7033.

Yours truly,

Dennis J. Brown

Mr. Dennis J. Brown,
Head,
Water Standards and Studies.

DJB/ja

c.c. M. Morelli

b.c.c. A. Beck

MANITOBA

Inter-Departmental Memo

PS-1

Date April 1, 1985

To Dr. P. Warner,
Director,
Environmental Health Services,
831 Portage Avenue.

From Dennis Brown, Head,
Water Standards and Studies.

Telephone

Subject EFFECTS OF AIRBORNE PARTICULATES IN THE FLIN FLON AREA

First | Fold

Mr. Bill Leefe, Smelter Safety Committee Co-Chairperson, contacted Water Standards and Studies regarding the environmental effects of airborne particulates in the Flin Flon area. (Refer to attachment.) Since the particulates had originated from the tailings containment area, Mr. Leefe was concerned firstly about the nature of the particulates and, secondly, about the implications for human health and impacts upon wildlife and local lakes.

Water Standards and Studies conducted a field study of this matter during the week of January 7-11, 1985. Our preliminary results indicate that iron and sulphate were the active substances deposited in concentrations attributable to a tailings source. Substantial depositions of zinc, copper and cadmium as well as some sulphate and iron were also present but were attributable to fallout from smelter stack emissions. (This latter phenomenon has been well documented by a number of investigators including Phillips et al (1983)* and Franzin et al (1979)**)

Calculated isopleths of the loading rates for iron and sulphate are appended. It would be appreciated if you could assess the implications of these loadings with respect to human health. Please respond directly to Mr. Leefe. Should you require further information, please contact me at 945-7033.

D. Brown.

Attachment
cc: B. Leefe
M. Morelli

bcc: A. Beck

* Phillips, S. F., D. L. Wotton, D. B. McEachern and D. C. Jones. 1983. Snow Chemistry in the Flin Flon Area of Manitoba. Terrestrial Standards and Studies Report #83-13. Environmental Management Division, Manitoba Department of Environment and Workplace Safety and Health. Winnipeg.

** Franzin, W. G., G. A. McFarlane and A. Lutz. 1979. Atmospheric Fallout in the Vicinity of a Base Metal Smelter at Flin Flon, Manitoba, Canada. Environ. Sci. Technol., 13: 1513-1521.

MANITOBA

Inter-Departmental Memo

Date April 1, 1985

To D. L. Wotton, Head,
Terrestrial Standards and Studies.

From Dennis Brown, Head,
Water Standards and Studies.

Telephone

Subject EFFECTS OF AIRBORNE PARTICULATES IN THE FLIN FLON AREA

Mr. Bill Leefe, Smelter Safety Committee Co-Chairperson, contacted Water Standards and Studies regarding the environmental effects of airborne particulates in the Flin Flon area. (Refer to attachment.) Since the particulates had originated from the tailings containment area, Mr. Leefe was concerned firstly about the nature of the particulates and, secondly, about the implications for human health and impacts upon wildlife and local lakes.

Water Standards and Studies conducted a field study of this matter during the week of January 7-11, 1985. Out preliminary results indicate that iron and sulphate were the active substances deposited in concentrations attributable to a tailings source. Substantial depositions of sinc, copper and cadmium as well as some sulphate and iron were also present but were attributable to fallout from smelter stack emissions. (This latter phenomenon has been well documented by a number of investigators including Phillips et al (1983)* and Franzin et al (1979)**.)

Calculated isopleths of the loading rates for iron and sulphate are appended. It would be appreciated if you could assess the implications of these loadings with respect to wildlife. Please respond directly to Mr. Leefe. Should you require further information, please contact me at 945-7033.

D. Brown.

Attachment

cc: B. Leefe
M. Morelli
bcc: A. Beck

* Phillips, S. F., D. L. Wotton, D. B. McEachern and D. C. Jones. 1983. Snow Chemistry in the Flin Flon Area of Manitoba. Terrestrial Standards and Studies Report #83-13. Environmental Management Division, Manitoba Department of Environment and Workplace Safety and Health. Winnipeg.

** Franzin, W. G., G. A. McFarlane and A. Lutz. 1979. Atmospheric Fallout in the Vicinity of a Base Metal Smelter at Flin Flon, Manitoba. Canada. Environ. Sci. Technol., 13: 1513-1521.

COPY

April 1, 1985

Mr. Bill Leefe,
Smelter Safety Committee Co-Chairperson,
United Steelworkers of America,
District 3, Local 7106,
68 Church Street,
FLIN FLON, Manitoba.
R8A 1K7

Dear Mr. Leefe:

It is my pleasure to report on our progress to date regarding the concerns expressed in your letter of November 27, 1984.

As I had proposed in my letter of December 11, 1984, Water Standards and Studies staff did indeed conduct field work in the Flin Flon area during the week of January 7-11, 1985. Samples of snow, ice and water were collected from 26 sites located within 10 kilometres of the smelter. Analyses have recently been completed and a formal report is currently in preparation.

Preliminary assessment of our data indicates that iron and sulphate were the active substances originating from the tailings that had been deposited on surrounding areas in concentrations distinguishable from background. Concentrations of other metals such as zinc, copper, lead and cadmium could not be distinguished from background and were not attributable to tailings particulates. (Background in this study has been defined as the sum of natural surficial occurrances plus fallout from smelter stack emissions.) Our preliminary calculations suggest that the bulk of iron deposition attributable to tailings particulates lies within one kilometre of the smelter stack. The bulk of sulphate deposition attributable to tailings particulates lies within four kilometres of the smelter stack.

The implications of these loadings upon lakes are under review. Additionally, we have solicited the advice of Environmental Health Services Branch and of the Terrestrial Standards and Studies Section regarding effects upon people and effects upon wildlife. Immediate corrective action such as removal of particulates from the lake surface is not warranted because neither iron nor sulphate are critical environmental contaminants. Additionally, particulates had became embedded in the lake surface by early January, 1985; thus rendering removal prohibitively expensive.

We will forward a copy of the final report upon completion. Meanwhile, should you require further information, please call me at 1-945-7033.

Yours truly,

Dennis Brown

Dennis Brown, Head,
Water Standards and Studies.

AB/lp

bcc: A. Beck

APPENDIX 2(a): Sampling Site and Sample Characteristics

Site	Waterbody (Lake)	Direction From Stack	Distance From Stack (Km)	Snow Depth (cm)	Depth of Ice Excavation (cm)	Sample Weight (g)
1	Manistikwan	E	5.3	14	2.5	791.9
2	Manistikwan	E	6.1	14	2.5	456.2
3	Manistikwan	E	9.0	10	2.5	485.9
4	Manistikwan	ESE	5.7	14	2.5	1143.9
5	Manistikwan	ESE	7.0	12	2.5	502.3
6	Manistikwan	ESE	7.5	19	2.5	804.0
7	Manistikwan	ESE	8.5	8	2.5	456.3
8	Embury	NNE	7.6	8	2.5	424.2
9	Embury	NE	7.3	7	2.5	315.3
10	Embury	NE	8.4	8	2.5	308.0
11	Embury	ENE	7.1	10.5	2.5	433.4
12	Embury	ENE	7.6	13	2.5	531.3
13	Cliff	NNE	4.7	8	5	415.3
14	Cliff	NNE	5.7	13	5	405.9
15	Cliff	NE	3.7	21	5	786.5
16	Cliff	NE	4.2	13	5	523.9
17	Grant	ENE	3.3	10	5	1113.7
18	Unnamed	ENE	4.7	10	10	490.2
19	Ross	ENE	1.7	17	15	1502.3
20	Ross	E	1.6	12	15	1388.6
21	Ross	E	1.9	5	30	2338.5
22	Ross	E	1.5	15	15	1635.1
23	Ross	E	1.2	14	15	1486.2
24	Ross	SE	1.9	12	15	1503.7
25	Schist	SE	4.6	13	12	1235.5
26	Schist	SE	5.2	18.5	10	1568.1

APPENDIX 2(b): Metal and Sulphate Concentrations in Thawed Snow - Ice Samples

Site	Cd (mg/L)	Cu (mg/L)	Pb (mg/L)	Ni (mg/L)	Zn (mg/L)	Fe (mg/L)	SO_4 (mg/L)
1	0.004	0.61	0.005	<0.005	3.90	0.12	6.45
2	0.005	0.15	0.006	<0.005	1.60	0.02	3.05
3	0.003	0.06	<0.005	<0.005	1.20	<0.02	1.45
4	0.005	0.06	<0.005	<0.005	0.96	0.06	8.80
5	0.008	0.41	0.014	<0.005	4.75	0.10	6.70
6	0.004	0.04	0.005	<0.005	1.42	<0.02	3.15
7	0.005	0.06	0.005	<0.005	1.63	0.02	1.20
8	0.001	0.009	<0.005	<0.005	0.31	0.02	4.15
9	0.010	0.05	0.007	<0.005	2.94	<0.02	3.00
10	0.007	0.06	<0.005	<0.005	1.27	<0.02	0.90
11	0.011	0.08	0.010	<0.005	1.64	0.02	9.80
12	0.007	0.06	0.011	<0.005	1.88	0.02	7.20
13	0.003	0.04	0.006	<0.005	0.76	0.02	13.80
14	0.009	0.07	0.010	<0.005	3.23	0.02	4.40
15	0.009	0.23	0.020	<0.005	5.22	0.02	4.20
16	0.004	0.13	0.009	<0.005	1.81	0.03	4.10
17	0.005	0.28	0.009	<0.005	2.83	0.17	3.70
18	0.004	0.06	0.007	<0.005	1.09	0.02	1.90
19	0.007	0.25	<0.005	<0.005	2.46	0.10	37.30
20	0.018	0.75	<0.005	<0.005	6.31	0.57	178.
21	0.006	0.09	<0.005	<0.005	1.78	0.33	113.
22	0.008	0.25	<0.005	<0.005	3.09	0.20	35.0
23	0.009	0.21	0.005	<0.005	1.82	0.08	27.0
24	0.010	0.24	<0.005	<0.005	2.31	0.09	82.5
25	0.006	0.23	<0.005	<0.005	2.42	0.32	70.0
26	0.003	0.05	<0.005	<0.005	1.11	0.02	70.0

APPENDIX 2(c): Metal and Sulphate Total Calculated Depositions

Site	Cd (mg/m^2)	Cu (mg/m^2)	Pb (mg/m^2)	Ni (mg/m^2)	Zn (mg/m^2)	Fe (mg/m^2)	SO_4 (mg/m^2)
1	0.317	48.31	0.396	N.D.	308.84	9.50	510.78
2	0.228	6.84	0.274	N.D.	72.99	0.91	139.14
3	0.146	2.92	N.D.	N.D.	58.31	N.D.	70.46
4	0.572	6.86	N.D.	N.D.	109.81	6.86	1006.63
5	0.402	20.59	0.703	N.D.	238.59	5.02	336.54
6	0.322	3.22	0.402	N.D.	114.17	N.D.	253.26
7	0.228	2.74	0.228	N.D.	74.38	0.91	54.76
8	0.042	0.38	N.D.	N.D.	13.15	0.85	176.04
9	0.315	1.58	0.221	N.D.	92.70	N.D.	94.59
10	0.216	1.85	N.D.	N.D.	39.12	N.D.	27.72
11	0.477	3.47	0.433	N.D.	71.08	0.87	424.73
12	0.372	3.19	0.584	N.D.	99.88	1.06	382.54
13	0.125	1.66	0.249	N.D.	31.56	0.83	573.11
14	0.365	2.84	0.406	N.D.	131.11	0.81	178.60
15	0.708	18.09	1.573	N.D.	410.55	1.57	330.33
16	0.210	6.81	0.472	N.D.	94.83	1.57	214.80
17	0.557	31.18	1.002	N.D.	315.80	18.93	412.07
18	0.196	2.94	0.343	N.D.	53.43	0.98	93.14
19	1.052	37.56	N.D.	N.D.	369.57	15.02	285.44
20	2.499	104.15	N.D.	N.D.	876.21	79.15	24,717.08
21	1.403	21.05	N.D.	N.D.	416.25	77.17	26,425.05
22	1.308	40.88	N.D.	N.D.	505.25	32.70	5,722.85
23	1.338	31.21	0.743	N.D.	270.49	11.89	4,012.74
24	1.504	36.09	N.D.	N.D.	347.35	13.53	12,405.53
25	0.741	28.42	N.D.	N.D.	298.99	39.54	8,648.50
26	0.470	7.84	N.D.	N.D.	174.06	3.14	10,976.70

*"N.D." denotes that the metal in question was not detected in the snow samples.

APPENDIX 2(d): Water Chemistry Results

Site	Conductivity (µS/cm)	pH (Units)	Total Alkalinity ($CACO_3$mg/L)	Alkalinity (HCO_3mg/L)	Ext As (mg/L)	Ext CD (mg/L)	Ext Cu (mg/l)	Ext Pb (mg/L)	Ext Ni (mg/L)	Ext Zn (mg/L)	Ext Ca (mg/L)	Ext Mg (mg/l)	Hardness ($CaCO_3$mg/L)	Ext Fe (mg/L)
1	172.	7.55	66.0	80.5	0.003	0.001	0.01	<0.005	<0.005	0.41	24.9	7.40	92.6	<0.02
2	127.	7.55	46.0	56.0	<0.001	<0.001	0.01	<0.005	<0.005	0.24	18.6	5.12	67.6	<0.02
3	170.	7.40	66.0	80.5	0.003	0.001	0.01	<0.005	<0.005	0.38	25.3	7.76	95.2	<0.02
4	172.	7.65	66.0	80.5	0.003	0.001	0.01	<0.005	<0.005	0.39	25.0	7.30	92.5	<0.02
5	174.	7.65	68.0	83.0	0.003	0.001	0.01	<0.005	<0.005	0.46	26.0	7.58	96.2	<0.02
6	178.	7.75	68.0	83.0	0.003	0.001	0.01	<0.005	<0.005	0.45	26.5	7.92	98.6	<0.02
7	177.	7.65	68.0	83.0	0.003	0.002	0.01	<0.005	<0.005	0.46	27.0	8.20	101.	<0.02
8	127.	7.40	46.0	56.1	0.003	0.001	0.01	<0.005	<0.005	0.28	19.5	5.40	70.2	<0.02
9	146.*	5.55*	8.00*	9.76*	<0.001	0.001	0.01	<0.005	<0.005	0.26	19.4	5.34	70.5	<0.02
10	129.	7.55	48.0	58.6	<0.001	0.001	0.01	<0.005	<0.005	0.28	18.6	5.14	67.6	0.02
11	129.	7.65	46.0	56.1	<0.00.	0.001	0.01	<0.005	<0.005	0.35	18.8	5.19	68.4	0.03
12	131.	7.45	48.0	58.6	<0.001	0.001	0.01	<0.005	0.010	0.28	18.6	5.10	67.5	<0.02
13	134.	7.65	48.0	58.6	0.002	0.001	0.01	<0.005	<0.005	0.22	19.0	5.30	69.3	<0.02
14	123.	7.50	46.0	56.1	<0.001	0.001	0.01	<0.005	<0.005	0.27	18.3	5.11	67.0	0.02
15	126.	7.65	48.0	58.6	0.002	0.001	<0.01	<0.005	<0.005	0.29	18.5	5.16	67.2	<0.02
16	137.	7.50	50.0	61.0	0.002	0.001	0.01	<0.005	0.006	0.33	20.0	5.57	72.9	<0.02
17	238.	6.80	94.0	115.	0.002	0.001	0.01	<0.005	<0.005	0.39	38.0	8.10	128.	0.22
18	106.	6.65	46.0	56.1	0.002	0.001	0.03	<0.005	<0.005	0.79	17.5	4.08	60.8	0.42
19	1780.	6.80	34.0	41.5	0.002	0.009	0.03	<0.005	<0.005	1.90	270.	15.0	737.	0.08
20	1700.	6.70	38.0	46.4	0.009	0.005	0.03	<0.005	<0.005	2.08	250.	15.0	687.	0.10
21	1660.	6.70	34.0	41.5	<0.001	0.008	0.03	<0.005	0.010	2.06	250.	15.0	687.	0.10
22	1670.	6.75	36.0	43.9	<0.001	0.010	0.03	0.005	<0.005	2.17	260.	15.0	711.	0.05
23	1570.	6.70	42.0	51.2	<0.001	0.010	0.03	<0.005	0.012	2.55	248.	15.7	685.	0.09
24	1710.	6.65	32.0	39.0	<0.001	0.010	0.03	<0.005	<0.005	2.10	265.	15.7	727.	0.05
25	869.	7.20	72.0	87.8	0.002	<0.001	<0.01	<0.005	<0.005	0.41	139.	13.0	402.	<0.02
26	874.	7.45	70.0	85.4	0.003	<0.001	<0.01	<0.005	0.010	0.37	130.	12.8	378.	<0.02

* Suspect value